Admission Control Policies for WCDMA Satellite Return Link in an Avionic Environment

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6th European Workshop on Mobile/Personal SatComs EMPS 2004
2nd Advanced Satellite Mobile Systems Conference ASMS 2004

ESA-ESTEC Noordwijk – The Netherlands
Outline

- Introduction
- System Architecture
- Service Provision
- Admission Control Policies
  - Fixed Threshold admission control
  - Effective Bandwidth admission control
- Result analysis
Introduction

- **In-Flight Entertainment**
  - Goal: supply passengers with multimedia services
    (broadband Internet access, real-time communications,…)

- **Broadband Communication**
  - bi-directional high bandwidth satellites working in *Ku band*

**EU NATACHA project**
System Architecture

APC, Pax. Data Services
Cabin Crew Data Service
On board Router
Airborne System
Cockpit Data Service
Broadband Communication Equipment

Shared Communication Resource

Ground Station
Satellite Data Link

- Constellation of geostationary satellite working in Ku band

- **Return link** based on **Code Division Multiple Access**
  - Flexibility for an high mobility environment

- Radio Resource Management issues:
  - Power control
  - Admission control
  - Congestion control (data scheduler)
  - Bandwidth allocation
Service Provision

- **IP** based services:
  - Voice over IP
  - Video-conferencing
  - Web browsing
  - File transfer

- Introduction of **Classes of Service** for QoS guarantees

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<th>Class of Service</th>
<th>Conversational Class</th>
<th>Interactive Class</th>
<th>Background Class</th>
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<td>VBR bursty</td>
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Service Provision

- **Centralized architecture**
- **Ground Station** controls
  - connection access to the network
  - resource reservation
- **Connection set-up phase:**
  - each connection has to declare its *QoS profile*

<table>
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<tr>
<th>QoS Profile</th>
<th>Traffic class</th>
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Bit rate decreasing

OVSF code tree
(one per A/C)

Subtree (set of codes) assigned to a given connection.

One DCH assigned to each connection basing on the declared *QoS profile*
Admission Control Policies

- **Main problems:**
  - keep interference low enough to save QoS of already accepted connections
  - high system capacity
- **Two approaches** are introduced:
  - *Fixed threshold admission control*
  - *Effective bandwidth admission control*
- Admission control rules applied only to **guaranteed bit rate classes**
- A data **scheduler** based on *Earliest Deadline First* discipline is adopted for both the admission control approaches
Admission Control Policies

- **Fixed Threshold Admission Control**
  - Model based algorithm
  - Based on throughput admission control, typically adopted in a terrestrial environment

- **Effective Bandwidth Admission Control**
  - Based on:
    - Effective Bandwidth concept
    - Minimum Power Allocation Algorithm
  - Traffic sources:
    - Limit of Gaussian approximation
    - Solution for bursty sources
Fixed Threshold Admission Control

Not manageable load factor

\[ \eta_{nm} = (1 + f) \sum_{j=1}^{N} \frac{1}{1 + \frac{\hat{E}_b}{I_0} \cdot AF_j} \]

\[ f : \text{ inter-spot interference ratio} \]
\[ SF\_MAX : \text{max spreading factor} \]
\[ AF : \text{Activity Factor} \]
\[ \frac{\hat{E}_b}{I_0} : \text{Required SINR (QoS)} \]

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Minimum Power Allocation Algorithm

Goal:
given a number of DCHs with heterogeneous BER requirements to find the minimum received power of each code channel such that QoS requirements are satisfied

\[
\frac{E_b}{I_0} \quad \text{SINR of user } i, \text{ level } \nu
\]

\[
\frac{\hat{E}_b}{I_0} \quad \text{Required SINR of user } i
\]

\[
N \quad \text{Number of user in a spot}
\]

\[
M \quad \text{code levels on OVSF tree}
\]

\[
G_\nu \quad \text{Spreading Factor at level } \nu = 512/2^{\nu-1}
\]

\[
N_0 \quad \text{Thermal noise}
\]

\[
r_\nu = W / G_\nu \quad \text{Bit rate at level } \nu
\]

\[
C^i = \left[ C^i_1, \ldots, C^i_M \right] \quad \text{DCH associated to user } i
\]

\[
\Gamma_j = \sum_{l=1}^{M} \frac{C^j_l}{G_l}
\]

\[
A_i = \sum_{j \in AC_i} \left( \Gamma_j \cdot \frac{\hat{E}_b}{I_0} \right)
\]

\[
P^i_\nu \quad \text{Power rx of user } i \text{ at level } \nu
\]
Minimum Power Allocation Algorithm

\[ I^i_{TOT} = (1 + f) \cdot \left( \sum_{h=1}^{N} \sum_{m=1}^{M} C^h_m \cdot P^h_m \right) - \sum_{j \in AC_i} \sum_{l=1}^{M} C^j_l \cdot P^j_l \]

- Total interference for user \( i \)

\[ \frac{E^i_b}{I_0} = \left. \frac{P^i_v \cdot G_v}{I^i_{TOT} + N_0} \right| > \left. \frac{\hat{E}^i_b}{I_0} \right| \]

- Condition to evaluate the lower power needed to meet required SINR

\[ P^i_v = \frac{N_0 \cdot \hat{E}^i_b}{I_0} \cdot \left[ G_v \cdot [1 + A_i] \cdot \left[ 1 - (1 + f) \cdot \sum_{q=1}^{N_{AC}} \frac{A_q}{1 + A_q} \right] \right] \]

- Minimum Received Power for user \( i \) at level \( v \) to satisfy BER requirements
Minimum Power Allocation Algorithm

\[
\sum_{h=1}^{N} \left( \frac{\Gamma_h \cdot \hat{E}_b}{1 + A_h} \right) \leq \sum_{q=1}^{N_{AC}} \left( \frac{A_q}{1 + A_q} \right) \leq \frac{1 - \Delta}{1 + f}
\]

for every DCH of every user in the spot

\[
\Delta = \max_{v=1,...,M} \left[ \frac{N_0 \cdot \hat{E}_b}{I_0} \right] = \max \left[ \frac{N_0 \cdot \hat{E}_b}{I_0} \right] = \max \left[ \frac{N_0 \cdot \hat{E}_b}{G_v \cdot P_{v,max} \cdot I_0} \right]
\]

It depends on the maximum power for a single DCH (load factor has not to exceed its maximum)

\[
C = \frac{1 - \Delta}{1 + f}
\]

Normalized System Capacity

\[
R_h = \frac{\Gamma_h \cdot \hat{E}_b}{1 + A_h}
\]

Normalized Transmission Rate of user \( h \)

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Effective Bandwidth Admission Control

\[ \sum_{h=1}^{N} R_h = \sum_{k=1}^{K} \sum_{n_k=1}^{N_k} R_{n_k} \leq \frac{1-\Delta}{1+f} - R_{be} \]

- \( N \): number of guaranteed bandwidth connections
- \( K \): number of guaranteed bandwidth classes
- \( R_{be} \): system capacity reserved to Best effort class

\[ \Pr \left( \sum_{k=1}^{K} \sum_{n_k=1}^{N_k} R_{n_k} \leq \frac{1-\Delta}{1+f} - R_{be} \right) \geq \alpha \]

**Gaussian approximation:**
- connections are independent and identically distributed
- central limit theorem

\[ \sum_{n_k=1}^{N_k} R_{n_k} \quad \text{Gaussian r.v. where } \mu_k, \sigma_k^2 \text{ are mean and variance of } R_h \]

\[ G = \sum_{k=1}^{K} G_k \quad \text{Gaussian r.v. with } E[G] = \sum_{k=1}^{K} N_k \mu_k, \quad \text{Var}[G] = \sum_{k=1}^{K} N_k \sigma_k^2 \]

\( \alpha \): Satisfaction factor

**Admission Region**

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Effective Bandwidth Admission Control

Admission Region becomes:

\[
\Pr \left( G \leq \frac{1 - \Delta}{1 + f} - R_{be} \right) \geq \alpha \quad \Rightarrow \quad \frac{1 - \Delta}{1 + f} - R_{be} - E[G] \geq \beta
\]

with \( \beta \) defined as

\[
\frac{1}{\sqrt{2\pi}} \int_{\beta}^{\infty} e^{-t^2/2} dt = \frac{1}{2} \text{erfc} \left( \frac{\beta}{\sqrt{2}} \right) = 1 - \alpha
\]

\[
\sum_{k=1}^{K} N_k \mu_k + \beta \sqrt{\sum_{k=1}^{K} N_k \sigma_k^2} \leq \frac{1 - \Delta}{1 + f} - R_{be}
\]

Admission Region
Remarks on the Algorithm

Probability Density Function

![Probability Density Functions](image)

Web traffic (aggregated)

Voice traffic (aggregated)

Bit rates of Interactive sources are not independent

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Solution for Bursty Sources

Admission Region

\[
\left( N_1 \mu_1 + \beta \sqrt{N_1 \sigma_1^2} \right) + \left( R_{WEB} \right) \leq \frac{1 - \Delta}{1 + f} - R_{be}
\]

Moving average window

\[
R_{WEB} = \sum_{h=1}^{N_2} \bar{R}_h = \sum_{h=1}^{N_2} \left( \frac{\Gamma_h \cdot \hat{E}_b}{I_0} \cdot \frac{1}{1 + A} \cdot AF_{WEB} \right)_{SF\_MAX}
\]

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Simulation Results

Scenario 1:

- **VOICE**: (70-120) Request/min
- **WEB**: 90 Request/min
- **EMAIL**: 80 Request/min

Blocking probability

![VOICE Blocking Probability Graph]

![WEB Blocking Probability Graph]
Simulation Results

End-To-End Delay

Average ETE delay (VOICE)

Average ETE delay (WEB)

Average ETE delay (EMAIL)

Throughput

Average Througput (VOICE)

Average Througput (WEB)

Average Througput (EMAIL)
Simulation Results

Scenario 2:
- VOCE: 90 requests/min
- WEB: (80-130) requests/min
- EMAIL: 80 requests/min

Blocking probability

- AUDIO Blocking Probability
- WEB Blocking Probability

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Simulation Results

End-To-End Delay

**Average ETE delay (VOICE)**

- 0.26055
- 0.26555
- 0.27055
- 0.27555
- 0.28055
- 0.28555

80W 90W 100W 110W 120W 130W WEB Requests/min

**Average ETE delay (WEB)**

- 0.74115
- 0.75115
- 0.76115
- 0.77115
- 0.78115
- 0.79115

80W 90W 100W 110W 120W 130W WEB Requests/min

**Average ETE delay (EMAIL)**

- 0.684
- 0.704
- 0.724
- 0.744
- 0.764
- 0.784

80W 90W 100W 110W 120W 130W WEB Requests/min

Throughput

**Average Throughput (VOICE)**

- 2
- 2.02
- 2.04
- 2.06
- 2.08
- 2.1

80W 90W 100W 110W 120W 130W WEB Requests/min

**Average Throughput (WEB)**

- 0.25
- 0.27
- 0.29
- 0.31
- 0.33
- 0.35

80W 90W 100W 110W 120W 130W WEB Requests/min

**Average Throughput (EMAIL)**

- 0.11
- 0.112
- 0.114
- 0.116
- 0.118
- 0.12

80W 90W 100W 110W 120W 130W WEB Requests/min
Conclusions

- **Radio Resource Management** issues for a CDMA satellite return link

- **Admission Control policies**
  - Fixed threshold
  - Effective bandwidth
    - *Gaussian approximation*
    - *Moving average window*

- **Future work**
  - More general solutions for bursty sources
    - *Chernoff bound*
    - *Predicting algorithms*